Calculation No: NSTXU-CALC-11-032-00 **Revision No: 0**

Tile shaping of the IBDV Tiles

Purpose of Calculation: (Define why the calculation is being performed.)

Calculate the tile to tile and castellation to castellation gaps of the Inboard Divertor Horizontal tiles.

Codes and versions: (List all codes, if any, used)

Hand Calculations

References (List any source of design information including computer program titles and revision levels.)

1) NSTX-U SYSTEM REQUIREMENTS DOCUMENT NSTX-U-RQMT-SRD-003-01
2) RECOMMENDED MODIFICATION TO PFC SYSTEM REQUIREMENT DOCUMENT ON SURFACE SHAPING PFC-180706-MAJ-01

Assumptions (Identify all assumptions made as part of this calculation.)

Axisymmetric heat fluxes (specified in SRD), 0.004" surface profile tolerance on tiles, 0.015" profile tolerance of the baseplate tiles.

Calculation (Calculation is either documented here or attached)

See attached work sheets.

Conclusion (Specify whether or not the purpose of the calculation was accomplished.)

Tile to tile gap of 0.030" and castellation to castellation gap of 0.010" is sufficient to eliminate direct heating of the tile edge heating in forward helicity case.

Cognizant Individual (or designee) printed name, signature, and date

Andrei Khodak

Preparer's printed name, signature and date

Andrei Khodak Digitally signed by Andrei Khodak Date: 2018.09.28 15:22:20 -04'00'

I have reviewed this calculation and, to my professional satisfaction, it is properly performed and correct.

Checker's printed name, signature, and date

Michael Jaworski

Michael Jaworski Digitally signed by Michael Jaworski Date: 2018.09.28 14:59:50 -04'00'

Calculation

IBDV tile parameters are summarized in the table

				e-ed1441
Castellation gap	g_c	0.02	inch	Sht 1, I-4
Cast. Gap tol.	dg_c	0.005	inch	Sht 1, I-4
Tile gap	g_t	0.04	inch	Calc. assump
Tile gap tol.	dg_t	0.01	inch	Calc. assump
Grafoil Height	h_g	0.03	inch	
Grafoil Height tol.	dh_g	0.002	inch	
Tile Height	h_1	2.125	inch	Sht 1, D-6
Tile Height tol.	dh_1	0.004	inch	
Surface Profile tol	ds	0.004	inch	
Erosion "tolerance"	d_e	0.003	inch	
Tile Length (IBDV)	L_2	4.280	inch	Sht 1, F-11

Castellation jump can be calculated as follows:

$$h_c = (h_c + dh_c)\tan(\alpha) + d_e + d_s$$

Tile to tile jump can be calculated as follows:

$$h_t = (g_t + dg_t)\tan(\alpha) + d_e + 2\left(\frac{dh_1}{2} + dh_g + d_s\right) + dh_c$$

Center Stack surface shape dh_c is defined as the maximum tile to tile step height. From metrology data (fig. 1) 0.005” value is taken as a conservative assumption.

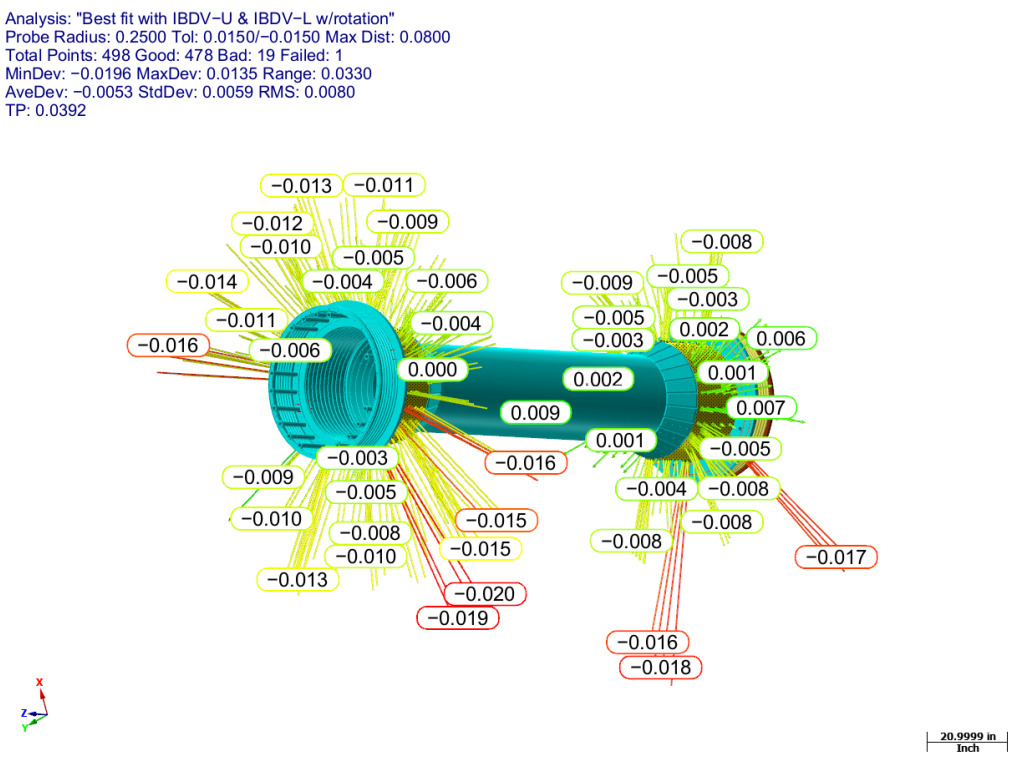


Fig 1. Center Stack Metrology data

With this additional requirement maximum tile to tile step on cooling plate dh_c is 0.005". For $\alpha = 5°$ the following values can be obtained:

$$h_c = 0.009187"$$

$$h_t = 0.028374"$$

The following rounded up values were used in the IBDV design:

$$h_c = 0.010"$$

$$h_t = 0.030"$$

Checks for Calculation No: NSTXU-CALC-11-32-00# Revision No: 00

Tile shaping of the IBDV Tiles

Component was checked against latest design

Yes. Drawing E-ED1441 was primarily used which is current.

All required load cases are included and current

Yes.

Discuss method used in the calculation

Calculation uses hand calculation relations to determine required step heights in the final design.

Discuss how the calculation was checked (*)

Independent examination of the relevant drawings is made to confirm values and calculations using the checker's implementation is used.

Fish-scale directionality is compared against SRD specification.

List issue identified and how they were resolved

No issues have been identified. The calculation report agrees with the checker's independent evaluation.

Checker's name: Michael Jaworski

Technical Authority: Robert Ellis Digitally signed by Robert Ellis Date: 2018.09.28 15:56:39 -04'00' (sign and date)

(*) independent calculations can be appended

Calculation Check:

An independent examination of the relevant drawings are made to fill in the checker's table.

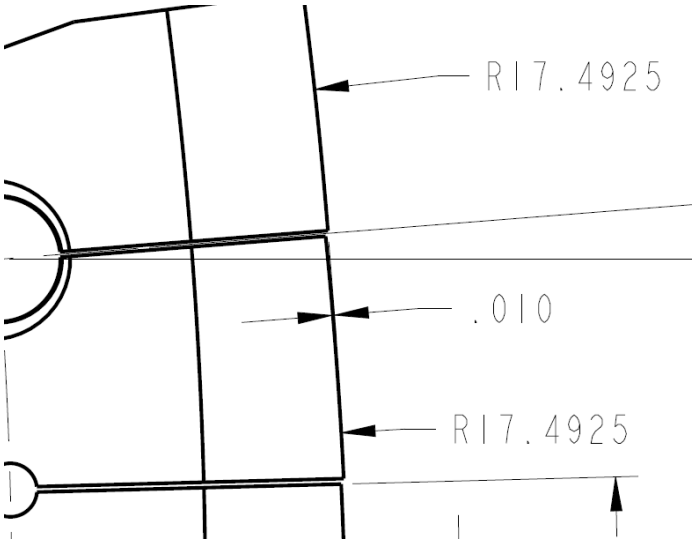
Key geometric features, Drawing E-ED1441				
Name	**Symbol**	**Value**	**unit**	**Drawing sht and quadrant**
Castellation gap	g_c	0.02	inch	sht 1, I-5
Cast. Gap tol	dg_c	0.005	inch	sht 1, I-5
Tile gap	g_t	0.04	inch	calc assump.
tile gap tol.	dg_t	0.004	inch	grafoil
Grafoil height	h_g	0.03	inch	grafoil spec
grafoil height tol	dh_g	0.002	inch	grafoil spec
Base plate height	h_b	0	inch	casing ref.
base plate tol	dh_b	0.003	inch	calc assump.
Tile height (typ)	h_1	2.044	inch	sht 1, A-9
tile height tol	dh_1	0.004	inch	surf. Profile
Surface profile tol	ds	0.004	inch	Calc. assump.
Erosion "tolerance"	d_e	0.003	inch	SRD
Tile length (IBDV)	L_2	4.58	inch	sht 1, C-9
N_CAST GAPS L2	N_2	4		

In this design, the "base plate" tolerance corresponds to the casing surface. The value of 0.003" (rounded up from 0.0025", half of 0.005") is based on metrology indicated in the calculation report.

The resulting values for h_c and h_t are:
h_t = 0.029"
h_c = 0.009"

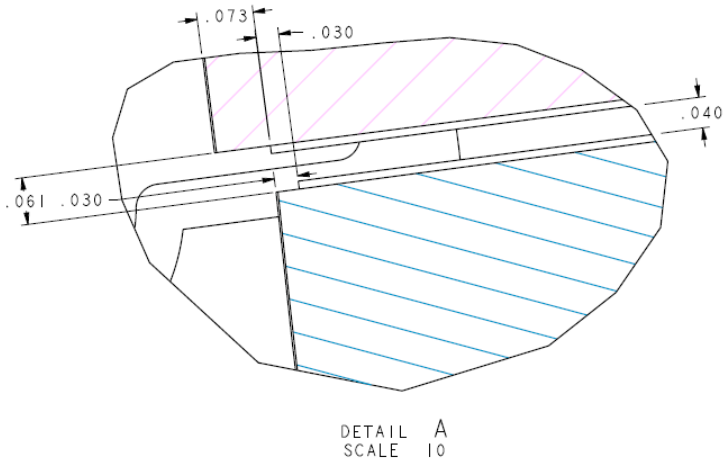
The calculation report reports 0.030" and 0.010" respectively.

These are checked against drawing E-ED1441, sht 1, zone B-10:



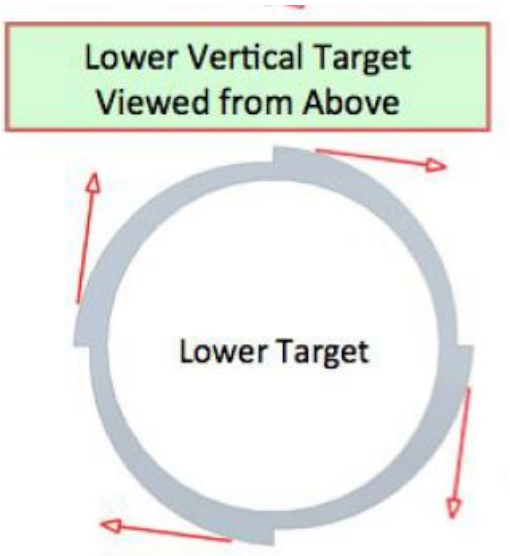
Which indicates the castellation step is 0.010".

Detail A of drawing E-ED1459 (in CSA section), sht 1 zone J-9 shows the tile-to-tile step height:



This verifies the stated values in the calculation are met.
All values match.

Directionality Check:
The same detail A of E-ED1459 shows the step increase in major radius when moving clockwise (viewing down). The corresponding SRD image is:



The SRD image also shows a step increase in major radius when moving clockwise (viewing downward). This matches the design drawings.

Minimum Requirements for Checking Calculations

1. Assure that inputs were correctly selected and incorporated into the design.

2. Calculation considers, as appropriate:

   - Performance Requirements (capacity, rating, system output)
   - Design Conditions (pressure, temperature, voltage, etc.)
   - Load Conditions (Electromagnetic (Lorentz Force), seismic, wind, thermal, dynamic)
   - Environmental Conditions (radiation zone, hazardous material, etc.)
   - Material Requirements
   - Structural Requirements (foundations, pipe supports, etc.)
   - Hydraulic Requirements (NPSH, pressure drops, etc.)
   - Chemistry Requirements
   - Electrical Requirements (power source, volts, raceway, and insulation)
   - Equipment Reliability (FMEA)
   - Failure Effects on Surrounding Equipment
   - Tolerance Buildup

3. Assumptions necessary to perform the design activity are adequately described and reasonable.

4. An appropriate calculation method was used.

5. The results are reasonable compared to the inputs.

6. Error bars (range) for inputs used, results / conclusions, assumptions, have been considered and are acceptable.

NOTE: IT IS THE RESPONSIBILITY OF THE CHECKER TO USE METHODS THAT WILL SUBSTANTIATE TO HIS/HER PROFESSIONAL SATISFACTION THAT THE CALCULATION IS CORRECT.

BY SIGNING CALCULATION, CHECKER ACKNOWLEDGES THAT THE CALCULATION HAS BEEN APPROPRIATELY CHECKED AND THAT THE APPLICABLE ITEMS LISTED ABOVE HAVE BEEN INCLUDED AS PART OF THE CHECK.